Volume 7
Number 97 *Germination and storage of apple seeds*

Article 1

October 1926

Germination and storage of apple seeds

A. L. Bakke
Iowa State College

H. W. Richey
Iowa State College

Kenneth Reeves
Iowa State College

October, 1926 Research Bulletin No. 97

GERMINATION AND STORAGE OF APPLE SEEDS

By A. L. Bakke, H. W. Richey and Kenneth Reeves

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

BOTANY SECTION

Ames, Iowa.

SUMMARY

Apple seeds will not germinate immediately after the fruit has become mature enough for picking. It is necessary for the seed to pass thru a stage of after-ripening.

The freshly extracted apple seed contains about 85 percent moisture. At room temperature approximately one-half of the moisture is lost during the first five days.

Soaking the seed prior to planting does not increase germination.

Ninety-one percent of apple seeds prevented from drying out when they were extracted from the fruit germinated. The best temperature for storage was found to be a temperature between 1° and 3° C. Seeds which had air dried germinated poorly in all cases.

Apple seeds which had been air dried and kept for a year did not germinate.

Apple seeds may be planted any time after Nov. 1. Where seeds are to be shipped long distances, special precaution must be made to keep the seeds from deteriorating.

The seed coat is not a factor in causing delayed germination.

GERMINATION AND STORAGE OF APPLE SEEDS

By A. L. Bakke, H. W. Richey and Kenneth Reeves.

It is generally known that the apple seed does not germinate at the time of harvesting under conditions considered as suitable for growth. Some time elapses before the after ripening period is completed. The after-ripening process may include either a transition in the seed coats, an alteration in the embryo itself, or both—changes which may be either physical or chemical.

Nurserymen recognize that apple seeds must be treated differently from many other commercial seeds before germination begins. Apple seeds are often placed in sand and exposed to the low freezing temperature of winter. This practice is called stratifying. Sometimes they are soaked and stored at a temperature slightly above freezing. The general opinion, however, is that the seeds must first be frozen. In nursery practice air dry seeds of French Crab, Vermont Seedlings or cider pomace are planted after being soaked and stratified, or else sown as soon as they are obtained in the fall.

With these methods of seed storage a stand of 20 to 50 percent is considered satisfactory. No method has previous to this time been developed to an efficiency which insures a high percentage of germination. In the present study, with attention directed to moisture and temperature in storage, a more satisfactory method has been found. The amount of moisture at which germination would most readily take place has been discovered and applied to the methods already in use.

REVIEW OF PREVIOUS WORK

The conditions which are successful in the germination of the apple seed are not necessarily associated with a freezing temperature for Davis and Rose (6) point out that the after-ripening in the hawthorn (*Crataegus mollis*) takes place at low temperatures (5° to 6° C.). If the seeds are removed from their carpels and kept moist at a temperature of 5° to 6° C., the latent period may be shortened 10 to 12 weeks. Eckerson (8) shows that a temperature of 5° or 6° C. produces the after-ripening status necessary for seeds of the hawthorn,

provided the seeds are kept moist. Jones (12) in his study of maple seeds also points out that a temperature about 5° C. is the optimum after-ripening temperature for those seeds. If the seeds are allowed to desiccate at higher temperatures, then vitality is lowered until the embryo fails to respond when placed under favorable germinating conditions. After-ripened seeds placed at 5° C. and kept saturated by snowpacks will retain their initial vigor for some time.

Delaven (7) using *Carya glabra, C. ovata, C. cordiformis, Quercus alba, Q. macrocarpa, Q. bicolor, Q. rubra,* and *Q. velutina,* seeds, comes to the conclusion that for storage a cold temperature even if the atmosphere is exceedingly moist is better than a warm dry storage environment. The fact that many of the seeds of *Quercus alba* had germinated at the time the seeds were collected, indicates the importance of the retention of moisture during the after-ripening process.

Chambliss (2) working upon the production of wild rice, finds that it is absolutely necessary to keep the seeds moist and at a low temperature. The safest method is to put the wet seed in cold storage or to store it out doors at a temperature near freezing so that fermentation will not occur. Where a small quantity of seeds is needed, it may be stored in receptacles which are securely anchored at the bottom of the stream in which the plants are to be grown. The seed may be shipped in a dry state during the first two weeks after harvest with a very small loss in vitality when packed in dry sphagnum. For late fall, winter or spring deliveries, the seeds must be transported in the wet state either in vessels containing water or in moist sphagnum.

Rose (17) demonstrates that *Tilia* seeds after-ripen and germinate at temperatures slightly above freezing. At 0° to 2° C. the seeds after-ripen but do not germinate. At 4° to 6° C. after-ripening and germination both took place. The experience of a nursery man who has had years of experience in the growing of trees and shrubs says that if *Tilia* seeds are allowed to become dry between the time of maturing and the time of stratification, a low percentage of germination results. On the other hand, if a high moisture content is maintained during this period, a high percentage of germination may be expected. In the case of *Sambucus* nursery men claim that stratification results in almost perfect germination if the seeds are not allowed to become dry between the time of maturing and the time of treatment.

Kidd and West (14) present information to the effect that soaking is detrimental to both germination and subsequent growth of the pea (*Pisum sativum*), dwarf bean (*Phaseolus vulgaris*), barley (*Hordeum*) and the sunflower (*Helianthus annuus*), even tho the time necessary for germination is apparently shortened. Tillotson (18) finds that coniferous seeds stored in

airtight containers remained viable longer than those in any other container which he tested.

Harrington (10) and Harrington and Hite (11) secured the greatest germination when the seeds were stored moist at a temperature slightly above freezing. It was immaterial whether they were removed from the fruit or kept in cold storage in the fruit. After ripening took place as rapidly in the fruit as it did when the seeds were extracted from the pulp. The seeds did not after-ripen satisfactorily in dry storage or when kept moist at a temperature of 20° C. or above. A low temperature (5°-10°C.) for a period of about two months was necessary. Freezing did not bring about germination.

EXPERIMENTAL STUDIES

From the evidence derived from the work previously carried on and from nursery practice, it is clear that two factors, moisture and temperature, are of utmost importance in causing germination to take place.

In the present study on the germination of the apple seed, attention then has been directed primarily to the question of moisture and temperature. An attempt was made to ascertain the exact amount of moisture necessary to cause the most effective after-ripening. The experimental work was undertaken with a view of ascertaining storage temperature which could be advocated in commercial practice.

MATERIALS AND METHODS

Seeds were obtained from two different sources: from Vermont, and from the State Orchard at Ames, Iowa. One shipment of the Vermont seed was secured in 1922 and stored dry in a tight container at room temperature. The second lot of Vermont seed was received November 13, 1922, a short time prior to the time active experimentation was begun. The second consignment had not been air dried and as a result had fermented enroute, leaving the seed in rather poor condition.

The seeds from the local orchard of the Pomology Section of the Iowa Experiment Station were from seedling stock trees of Ben Davis X Mother. The fruit was crushed in a cider mill, was then emptied into a pan of water and stirred for a short time to free the seed from the pulp so that it could settle at the bottom of the container. The seed was also thoroly washed afterwards. One portion of the local seed was air dried, while the remaining part was not allowed to become dry before being placed in storage.

Uniform, plump seeds were inserted directly into unstoppered glass vials which were deposited in quart fruit jars. To

provide a dry environment, calcium chloride was used while a layer of moist cotton gave the necessary humid condition. In all cases a wire shelf was provided so as to keep the vials and the seeds from coming in direct contact with the saturated cotton or the calcium chloride.

After the seeds had been exposed to the conditions desired they were planted in seed flats, in soil composed of three parts of compost and one part of sand. The seeds were covered with one-half inch of sand. The flats were kept in a cool greenhouse where the temperature was between 10° and 17° C. Plantings of twenty seeds each were made every fourth week from the time the seeds were taken from the fruit: five samples from each type of storage were planted. One sample was removed to the laboratory where the moisture content was determined.

The conditions of storage were arbitrarily chosen and were as follows:

1. Room temperature, 2. Common fruit storage (5° to 10° C.), 3. Fruit refrigeration (1° to 3° C.), 4. Refrigeration below freezing (0° to —2° C.). This was secured by placing the containers of an ordinary ice cream freezer with a brine mixture inside of fruit refrigeration chamber (3). 5. Variable temperature, (—25° to 10° C.).

For all moisture determination the seeds were dried in a vacuum oven.

LOSS OF WATER IN AIR DRYING

Recognizing the possibility of the importance of water in germination it was deemed advisable to determine the amount of water lost from freshly removed seeds held at room temperature in order to ascertain how long it would be safe to transport seeds. The proper amount of water elimination of intact fresh seeds was followed for: 4, 5, 7, 11, and 21 days. Percentages were calculated on basis of dry weight. The data are given in table I.

The fresh seeds, with an initial moisture of 84.79 percent, lost approximately one-half of that moisture during the first

TABLE I. MOISTURE LOSS FROM APPLE SEEDS RECENTLY EXTRACTED AND SUBJECTED TO ROOM TEMPERATURE

Duration of exposure	Dry weight of seeds (grams)	Loss of weight (grams)	Percent loss
	2.701	2.289	84.79
4 days	3.192	1.801	56.44
5 days	4.232	1.758	41.53
7 days	3.972	1.008	25.42
11 days	4.554	0.450	9.88
21 days	1.485	0.113	7.60

TABLE II. GERMINATION OF UNSOAKED AND SOAKED APPLE SEEDS PLANTED FEB. 24

Storage condition		No. of seeds germinating						Percent
		Mar. 3	7	10	13	17	20	germination
Common fruit Storage 5° to 10° C.	Soaked	–	6	13	14	17	17	85
	Not soaked	–	3	12	14	17	17	85
Fruit Refrigeration 1° to 3° C.	Soaked	2	7	10	13	15	15	75
	Not soaked	4	9	14	15	16	17	85
Refrigeration at and below zero 0° to –2° C.	Soaked	–	2	5	9	10	10	50
	Not soaked	–	2	3	5	7	8	40
Storage room temperature	Soaked	–	–	–	–	–	–	0
	Not soaked	–	–	–	–	–	–	0
Variable temperature (out of doors) 10° to –25° C.	Soaked	–	–	–	–	–	–	0
	Not soaked	–	–	–	–	–	–	0

five days; in 11 days the water content was reduced to 9.88 percent and in 21 days to 7.60 percent.

Attention should be given to the moisture content of the seed when air dried as well as to the water content of the seed at the time when it was removed from the fruit. During the early period of water evaporation the temperature would certainly vary. As the moisture decreased the resistance to water loss would be increased.

SOAKING SEEDS BEFORE PLANTING

Soaking seeds previous to planting has been done extensively as it was thought that germination would be increased. To determine adequately whether this practice produced the desired results, some seeds were taken from each storage location and divided into two parts. The first part was returned to storage while the other was soaked in distilled water at room temperature for 20 hours. On the following day the soaked and unsoaked seeds were planted in the same way as the other seeds on February 24. The time period involved and the total percentage of germination are given in table II.

In the data given in table II the seeds which were placed in common fruit storage (5° to 10° C.), had a total germination of 85 percent. At the observation periods the number of seeds germinating was about the same. The only extensive deviation was at the time of the first reading, March 7. At the fruit refrigeration temperature (1° to 3° C.) the seeds which were not soaked had the higher germination at each period of observation. The total germination was 15 for the soaked and 17 for the unsoaked seeds or 75 and 85 percent, respectively. Where the storage temperature was 0° to —2° C. the soaked

TABLE III. DATA SHOWING THE MOISTURE CONTENT OF APPLE SEEDS AFTER BEING PLACED IN STORAGE, AND AT TIME OF PLANTING WITH RESULTING GERMINATION PERCENT

Place of storage and condition		Kind of seed	Time of determination of percent moisture			Percent germination
			Jan. 6	Jan. 27	Feb. 24	
Room Temperature	Moist	Local	95.72	111.10	95.25	22.00
		Vermont	108.90	126.20	138.40	0.00
	Dry	Local	2.79	2.42	2.14	6.00
		Vermont	8.27	7.87	6.49	0.00
Common fruit storage, 5° to 10° C.	Moist	Local	99.07	115.30	69.56	62.00
		Vermont	54.33	69.65	88.01	11.25
	Dry	Local	3.59	3.81	4.05	10.00
		Vermont	6.89	6.64	4.41	0.00
Fruit Refrigeration 1° to 3° C.	Moist	Local	100.10	95.79	85.54	91.00
		Vermont	75.34	73.33	72.57	12.50
	Dry	Local	4.68	4.50	4.33	14.00
		Vermont	8.41	6.58	5.49	2.50
Refrigeration below zero, 0° to −2° C.	Moist	Local	94.00	88.26	100.34	66.00
		Vermont	55.80	35.30	60.34	5.00
	Dry	Local	6.77	8.05	5.70	0.00
		Vermont	10.18	8.27	7.51	0.00
Variable temperature 10° C. to −25° C.	Moist	Local	93.68	96.80	94.24	12.00
		Vermont	81.96	66.75	37.00	2.50
	Dry	Local	5.54	4.04	3.62	3.00
		Vermont	9.91	8.13	5.63	1.25

seeds gave the higher germination. The seeds stored in the room and stored out of doors did not germinate. From these results it would seem that little if any benefit would be gained by soaking.

RELATION OF MOISTURE CONTENT TO THE PERCENTAGE OF GERMINATION

It was thought that there might be a definite relationship between the amount of moisture in the seeds and the percentage of germination. The moisture content was determined when the seeds were placed in storage and at the time of planting. One-half of the seeds were used for germination tests and the other half in the determination of the moisture content.

From the observations in table III, the seeds kept moist gave the highest germination. However, the seeds stored moist at temperatures of 5° to 10° C. and 1° to 3° C. gave the highest germination. At the fruit refrigeration temperature 91 percent of the seeds grew. Even at this temperature 14 percent of the seeds stored dry, grew. However, the dry seeds had a consistently low percentage of germination. It is to be noted that the highest germination is closely associated with a high absorption with the exception of the seeds kept at room temperature. In these particular tests the Vermont seeds did not have as high a percentage of germination as the seeds secured locally.

RELATION OF THE TIME OF PLANTING TO GERMINATION

In the tests to ascertain the effect of time of planting 120 seeds were selected from each condition of storage, both dry and moist. In these series both local and Vermont seeds were used. The times for plantings were arbitrarily selected, Nov. 3, Dec. 1, Jan. 6, Jan. 27, and Feb. 4. In the case of the local seeds the plantings for Jan. 6 were disturbed so that the data could not be used.

The data as derived where the time of planting was considered, both for local and Vermont seeds, show that the local seeds are superior in germination to those obtained from Vermont. The highest germination, 93.75 percent, took place at the fruit refrigeration temperature. The storage condition where the temperature was at or below zero gave a germination of 71.25 percent; seed stored at common fruit storage temperature had a germination of 56.25 percent. In the case of the dry seeds, the highest germination occurred also at the fruit refrigeration temperature.

It is recognized that the data were not obtained early enough. At any rate the results show that it does not matter materially

TABLE IV. EXTENT OF GERMINATION FOR LOCAL AND VERMONT SEEDS UNDER DIFFERENT CONDITIONS OF STORAGE, PLANTED AT DIFFERENT PERIODS

Place and condition of storage		Kind of seed	No. of seeds germinating at different plantings					Total no. of seeds germinated	Percent germination
			Nov. 3	Dec. 1	Jan. 1	Jan. 27	Feb. 24		
Room temperature	Moist	Local	9	3	–	10	0	22	26.25
		Vermont	0	0	0	0	0	0	0
	Dry	Local	2	3	–	1	0	6	7.5
		Vermont	0	0	–	0	0	0	0
Common frut storage 5° to 10° C.	Moist	Local	11	6	–	11	17	45	56.25
		Vermont	–	1	0	4	4	9	11.25
	Dry	Local	6	4	–	0	0	10	12.50
		Vermont	0	0	0	0	0	0	0
Fruit refrigeration 1° to 3° C.	Moist	Local	19	20	–	20	16	75	93.75
		Vermont	–	1	1	4	4	10	12.50
	Dry	Local	8	1	–	5	0	14	16.25
		Vermont	0	0	0	2	0	2	2.5
Refrigeration at and below zero 0° to –2° C.	Moist	Local	16	16	–	16	9	57	71.25
		Vermont	–	0	0	1	3	4	5.00
	Dry	Local	0	0	0	0	0	0	0.00
		Vermont	–	0	0	0	0	0	0.00
Variable temperature 10° to –25° C.	Moist	Local	9	3	–	0	0	12	15.00
		Vermont	–	1	–	1	0	2	2.50
	Dry	Local	3	0	–	0	0	3	3.75
		Vermont	–	–	0	1	0	1	1.25

TABLE V. GERMINATION OF APPLE SEED KEPT FOR ONE YEAR COMPARED WITH GERMINATION OF FRESH SEED

Description of seed	Date planted	No. of seeds	Method	Beginning of germination	Total germination (Number)
Fresh seed	Oct. 6	50	Flat	March 1	22
One-year-old seed	Oct. 6	25	Flat	.....	0
Fresh seeds	Nov. 18	40	Petri dish	.....	0
Fresh seeds	Nov. 25	40	Petri dish	.....	0
Fresh seeds	Nov. 12	150	Petri dish	March 15	11

when the planting is done after Nov. 3. On Nov. 3 all the seeds but one germinated; on Dec. 1 and Jan. 27 all seeds grew, while on Feb. 24, 16 out of the 20 developed. From this it would appear that plantings might be made at any time after Nov. 1 to secure a high percentage of germination.

GERMINATION OF ONE-YEAR-OLD SEED STORED IN TIGHT CONTAINER AS COMPARED WITH FRESH SEED

Seeds are often stored in tight containers. The advisability of using fresh seed instead of seed which had been kept from the previous year was considered in the next series of experiments. The viability of the seeds was tested by the usual petri dish method and by planting the seeds in soil covered with a thin layer of sand and keeping the flats in a cool greenhouse. The data derived are given in table V.

From the data given in table V, which are somewhat meager, it is evident that the germination of the fresh seeds was extremely low, only 44 percent. No explanation can be given as to the cause of this. However, with the stored seeds there was no germination. It is also clear that the ordinary petri dish or laboratory method of germination is not satisfactory to test out the viability of apple seeds.

EFFECT OF TIME OF PLANTING UPON THE RATE GERMINATION

In the germination studies upon the apple seed, it was found that the seed would not germinate as soon as the fruit was mature for packing. However, on storage, the process of afterripening took place and within certain limits of time, the seed stored for the longer period did not require as long a time to germinate as the seed planted earlier. The data given in table VI have brought out this feature. Tests were made upon both fresh and dry seeds obtained directly from fruit in storage.

Plate I. Development of seedlings. Flat No. 1, 76 days, No. 2, 55 days, and No. 3, 34 days after planting. Seedlings from seed stored either moist or dry at 1° to 3° C. were considerably in advance of allothers.

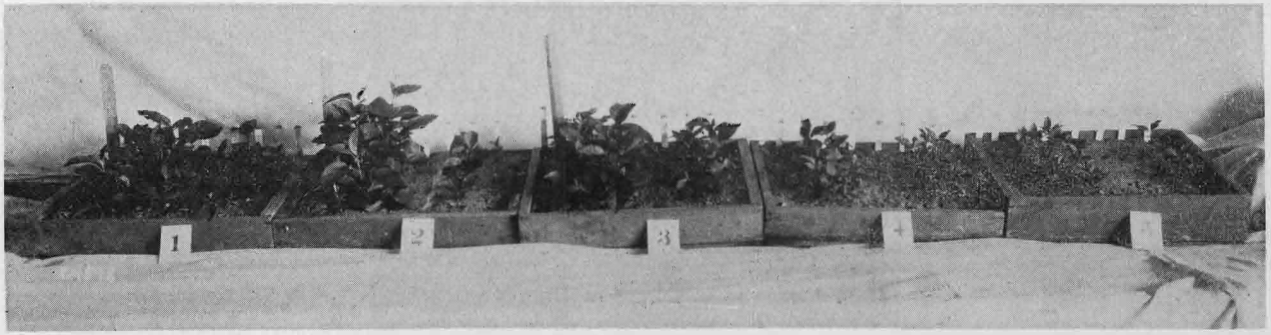

Plate II. Seedlings shown in this illustration are further advanced than those of Plate I. Nos. 1, 2, and 3 show growth 118 days, No. 4, 97 days, and No. 5, 76 days after planting.

TABLE VI. NUMBER OF DAYS NECESSARY FOR GERMINATION TO TAKE PLACE UNDER THE DIFFERENT CONDITIONS OF STORAGE; SEED WAS PLANTED AT DIFFERENT TIMES

Place and condition of storage		No. of days necessary for germination for seeds planted at different times							
		Nov. 3		Dec. 1		Jan. 27		Feb. 24	
		First	Last	First	Last	First	Last	First	Last
Room temperature	Moist	62	127	45	—	35	45	—	—
	Dry	62	108	68	—	52	—	—	—
Common fruit storage 5° to 10°C.	Moist	33	130	45	102	23	42	11	21
	Dry	74	96	68	106	—	—	—	—
Fruit refrigeration 1° to 3°C.	Moist	24	130	23	80	14	23	7	24
	Dry	61	124	88	—	35	49	—	—
Refrigeration at and below zero 0° to −2°C.	Moist	25	130	33	68	23	35	11	24
	Dry	—	—	—	—	—	—	—	—
Variable temperature (Out of doors) 10° to −25°C.	Moist	61	130	45	—	—	—	—	—
	Dry	73	—	—	—	—	—	—	—

From the data submitted in table VI the seeds kept from drying out germinated sooner in all cases with the exception of the first planting on Nov. 3. Thruout it was found that in nearly every case the seeds that were planted after the first of the year did not take as long to germinate as those planted earlier. Altho the total percentage of growing seeds is not given, still the seeds stored at a temperature between 1° to 3° C. gave the best results. The number of dry seeds which grew was very small, which in itself called attention again to the advisability of using seed which had not had an opportunity to dry out.

SEED COAT AS A FACTOR IN DELAYED GERMINATION

Delayed germination, according to Atwood (1) and Crocker (3, 4, 5), may be a seed coat character. To secure evidence of this fact seeds of the apple were placed in various concentrations of sulfuric acid ranging from concentrated acid to a solution of 0.8 percent for a period of one hour. One set had the seed coats removed mechanically, another set was scarified by

filing. The seeds were removed from the fruit and within two days were treated with the acid. After the seeds had been submerged in acid they were removed and carefully washed. The temperature used was about 22° C. The results secured were as follows: concentrated sulfuric acid, 12 percent; 50 percent sulfuric acid, 12 percent; 0.8 percent sulfuric acid, 10 percent. From the limited number of studies upon the effect of acids as well as the removal or scarification of the seed coat, it is evident that the seed coat is not concerned directly in the afterripening process of the apple. Whether the process involved in the apple seed is one of accumulated oxygen or whether certain inhibitors are present was not ascertained.

BIBLIOGRAPHY

(1) ATWOOD, WM.
1914. A Physiological Study of the Germination of Avena fatua. Bot. Gaz. **57**:386-414.

(2) CHAMBLISS, C. E.
1922. Wild Rice. Circ. U. S. Dept. of Agr., 229.

(3) CROCKER, WM.
1906. Role of the Seed Coat in Delayed Germination. Bot. Gaz. **42**:265-291.

(4) CROCKER, WM.
1909. Longevity of Seeds. Bot. Gaz. **47**:59-72.

(5) CROCKER, WM.
1916. Mechanics of Dormancy. Amer. Jour. Bot. **3**:99-120.

(6) DAVIS, W. E., AND ROSE, R. C.
1912. The Effect of External Conditions Upon the After-Ripening of the Seeds of Crategus mollis. Bot. Gaz. **54**:49-62, 1912.

(7) DELAVEN, C. C.
1915. The Relation of the Storage of the Seeds of Some of the Oaks and Hickories to Their Germination. Mich. Acad. Sci. Ann. Rpt. **17**:161-165.

(8) ECKERSON, SOPHIA
1913. A Physiological and Chemical Study of After-Ripening. Bot. Gaz. **50**:286-300.

(9) FAWCETT, H. S.
1908. Viability of Weed Seeds Under Different Conditions. Iowa Acad. Sci. Proc. **15**:25-45.

(10) HARRINGTON, G. T.
1923. Respiration of Apple Seeds. Jour. Agr. Research (U. S.) **23**:117-130.

(11) HARRINGTON AND HITE, BERTHA C.
1923. After-Ripening and Germination of Apple Seeds. Jour. Agr. Research (U. S.) **23**:153-161.

(12) JONES, H. A.
1920. Physiological Study of Maple Seeds. Bot. Gaz. **69**:127-151.

(13) KIDD, F., AND WEST, C.
1917. The Controlling Influence of Carbon Dioxide. Ann. Bot. **31**:457-487.

(14) KIDD, F., AND WEST, C.
1918. The Effect of Soaking Seed in Water. Ann. Appl. Biol. **5**:1-10.

(15) KIDD, F., AND WEST, C.
1920. Role of the Seed Coat in Relation to the Germination of Immature Seed. Ann. Bot. **34**:439-445.

(16) MAGNESS, J. R.
1920. Composition of Gases in Intercellular Spaces of Apples and Potatoes. Bot. Gaz. **70**:308-316.

(17) ROSE, R. C.
1919. Germination and After-Ripening. Bot. Gaz. **68**:281-308.

(18) TILOTSON, C. R.
1922. Storage of Coniferous Seeds. Jour. Agr. Research (U. S.) **22**:479-511.